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Abstract

ON THE LONG-TERM MECHANICAL PROPERTIES OF METALS USED AT ELEVATED TEMPERATURES AND SUBJECTED TO NEUTRON IRRADIATION

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The following two fundamental questions are discussed:

1) In what measure can thermodynamic extrapolation methods help us to determine the long-term properties of metals at elevated temperatures ?

2) Will it be possible to determine the long-term properties of metals irradiated by neutrons by an extension of the classical thermodynamic extrapolation methods for metals without irradiation ?

To (1):

By evaluation of the known results of in-pile relaxation tests, we conclude that thermodynamic extrapolation methods can be used for the case where irradiation by neutrons only produces interstitials and vacancies. Furthermore, we find that in this case it is sufficient to perform a few tests only under irradiation, and deduce from them and from tests without irradiation the long-term properties.

To (2):

The solution of this problem requires a careful analysis of the physical basis of the already known thermodynamic extrapolation

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methods. First of all, we have to see whether it is possible to express the complicated processes taking place during the creep of industrial steels by a simple Arrhenius equation. Furthermore, it will be necessary to clarify the influence of mechanical instability, such as formation of a constriction or intergranular fissures, on the long-term properties. Such an investigation will permit us to determine if time-to-rupture tests can partly be replaced by warm-hardness tests.

It is concluded that the simple Arrhenius equation gives only inaccurate results for the extrapolation of time-to-rupture tests of industrial alloys, and therefore a more complicated form has to be taken. This new form has an energy of activation and an entropy of activation, determined by another Arrhenius equation; and now the speed of creep as a function of the stress is no longer an exponential function, but a real iterate of logarithmic-exponential function, which is an extension of the first one.

From the investigation of the relations between the instability resulting from the formation of a constriction and the instability resulting from the formation of intergranular fissures, it is concluded that the form of the time-to-rupture curve (time-to-rupture as a function of the stress) is significantly influenced by the mechanical instability due to the formation of a constriction. It is not possible to describe this process by an Arrhenius equation. The thermodynamical evaluation of time-to-rupture tests with regard to the contraction of the broken specimens enables us to determine the influence of the geometrical instability. It has been found that the activation entropy for the formation of intergranular fissures shows the same dependence on the stress as the activation entropy for the creep process. From this behaviour, the conclusion can be drawn that the formation of intergranular fissures is initiated by nuclei developed during the creep process. This fact gives a basis for investigating to what extent time-to-rupture tests can be replaced by warm-hardness tests.